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UK CL (Edition J) F4V VGAC, H1K KPK
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(54) Solar-powered cooling/heating systems

(57) A cooling and/or heating system for the passenger compartment of a vehicle or for a building is at least partially powered by means of energy generated from photovoltaic cells mounted in modules (2, 3, 4) which are movable between retracted positions and operational positions in which they are adjacent windows of the vehicle. The modules (2, 3, 4) are substantially opaque so as to provide shade to the interior of the vehicle when they are in their operational positions. The or each module may be folded concertina fashion. Movement of the modules may be activated by use of the vehicle's ignition switch.

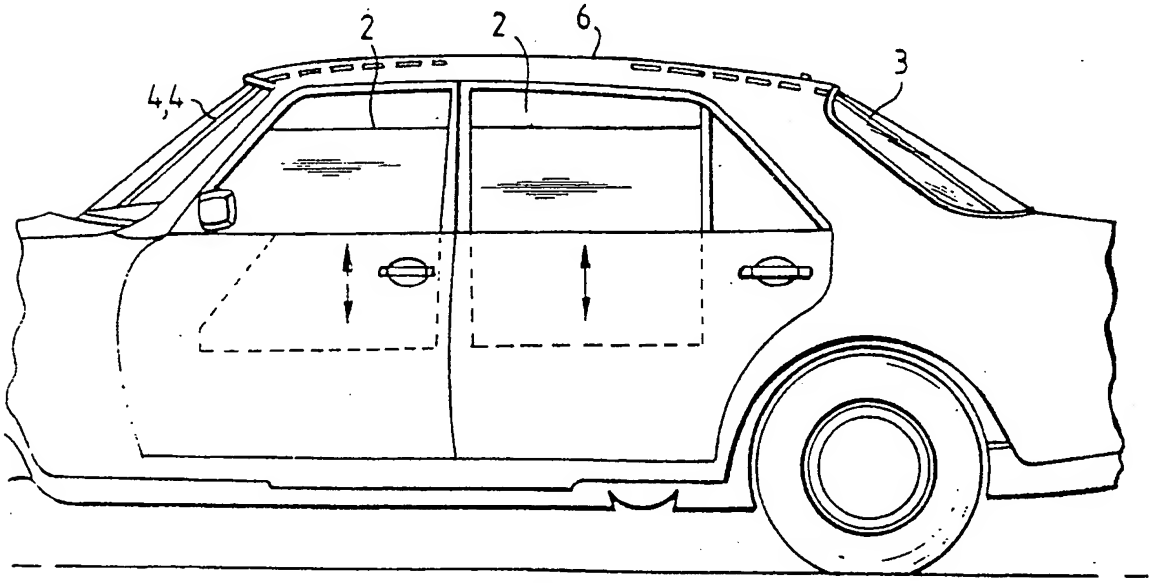

Fig.1.

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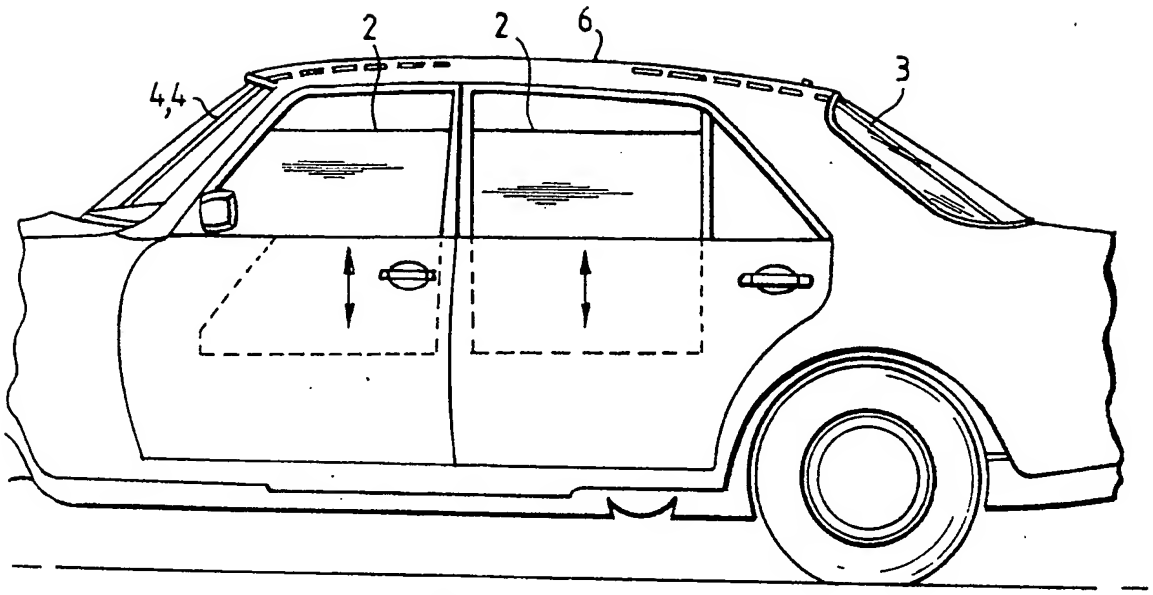

Fig.1.

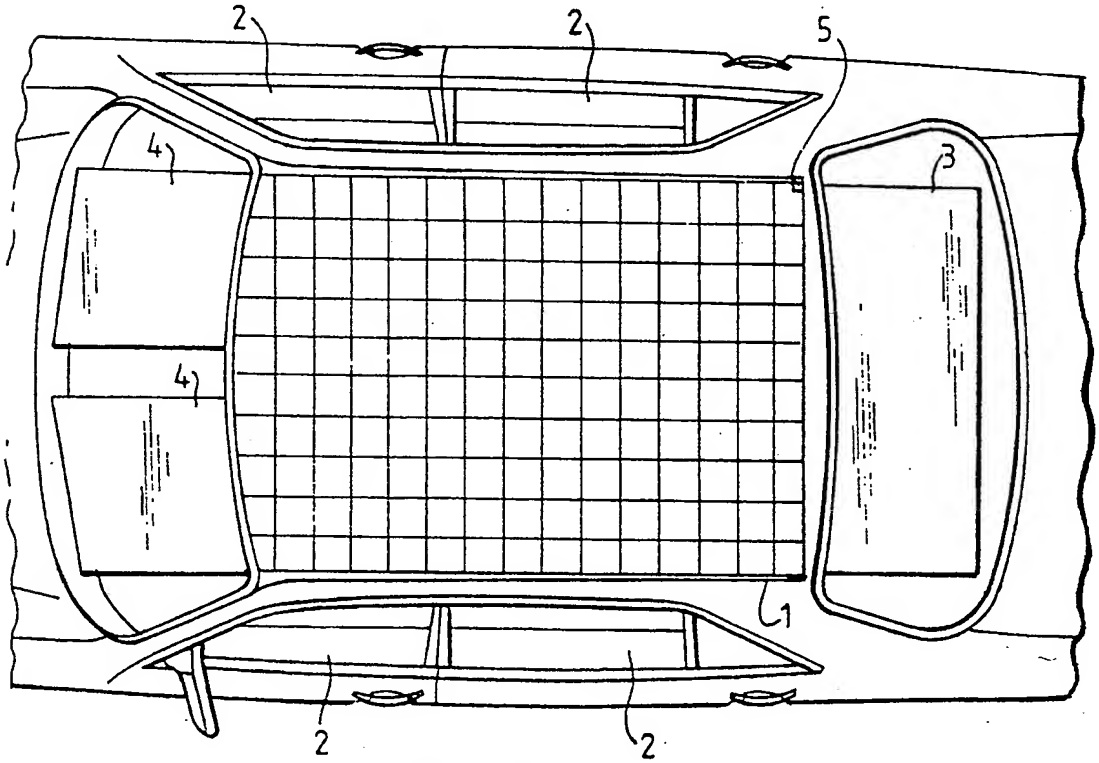

Fig.2.

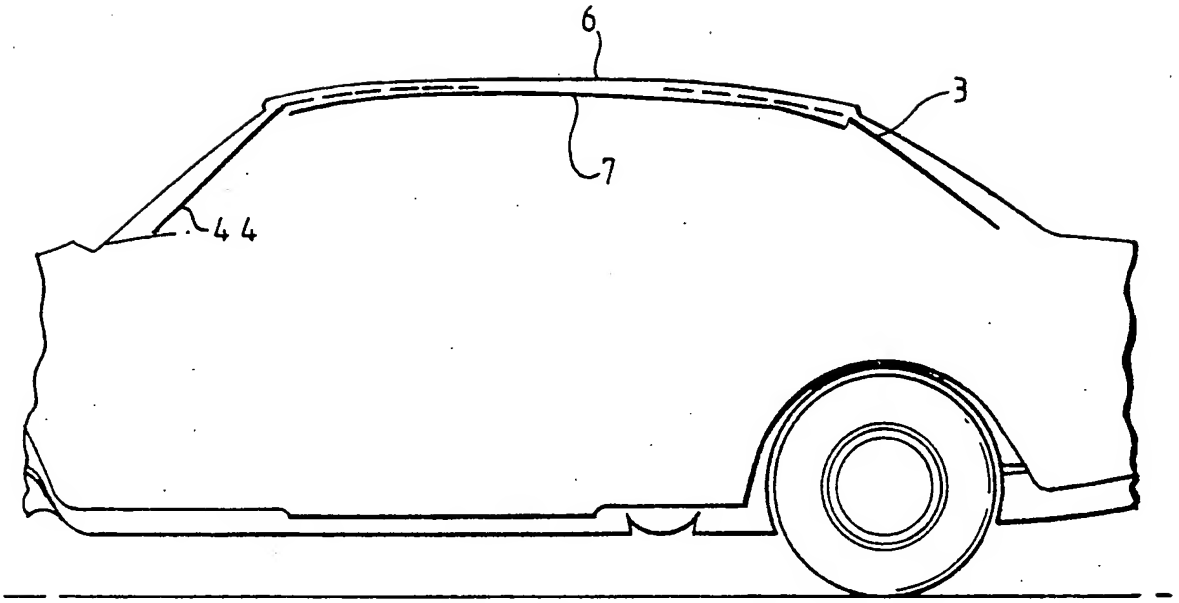

Fig.3.

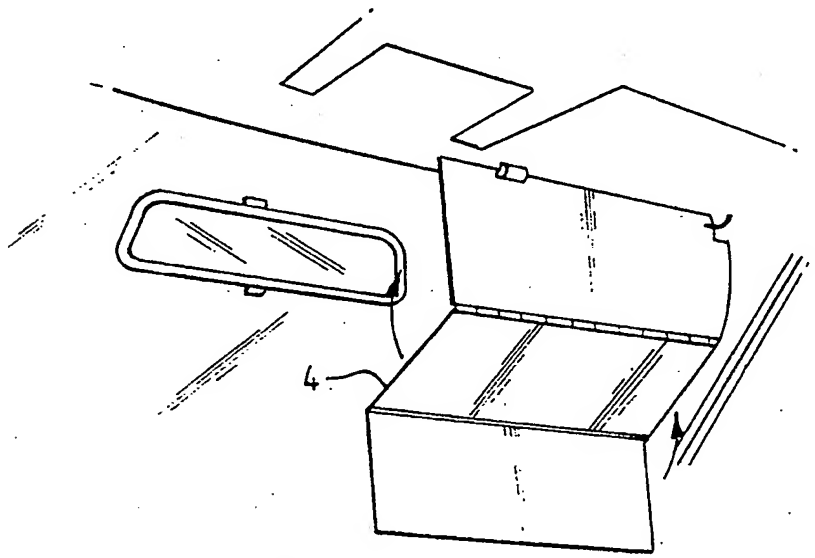

Fig.4.

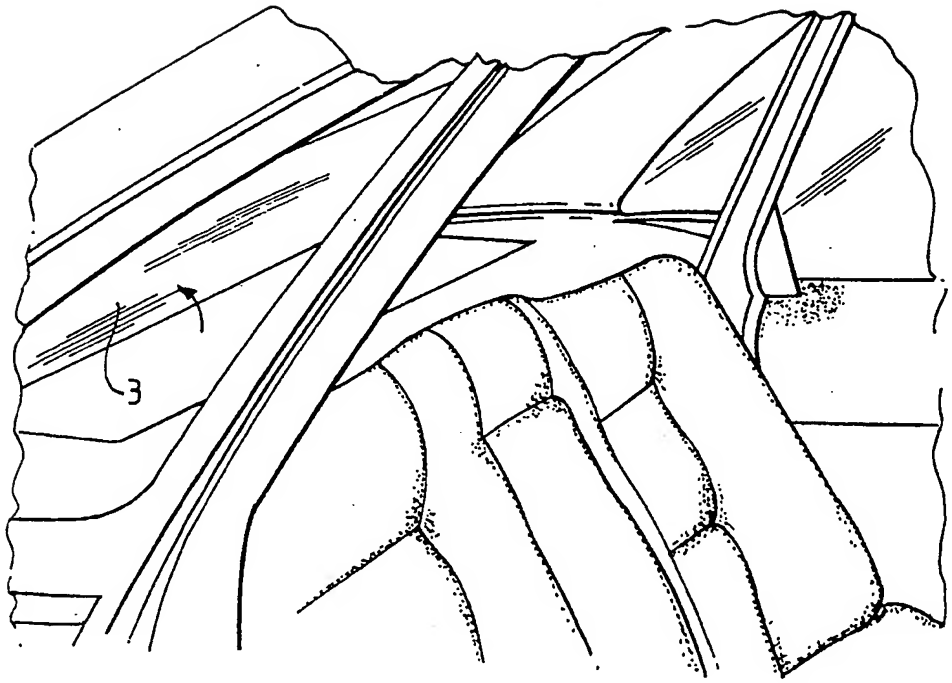

Fig.5.

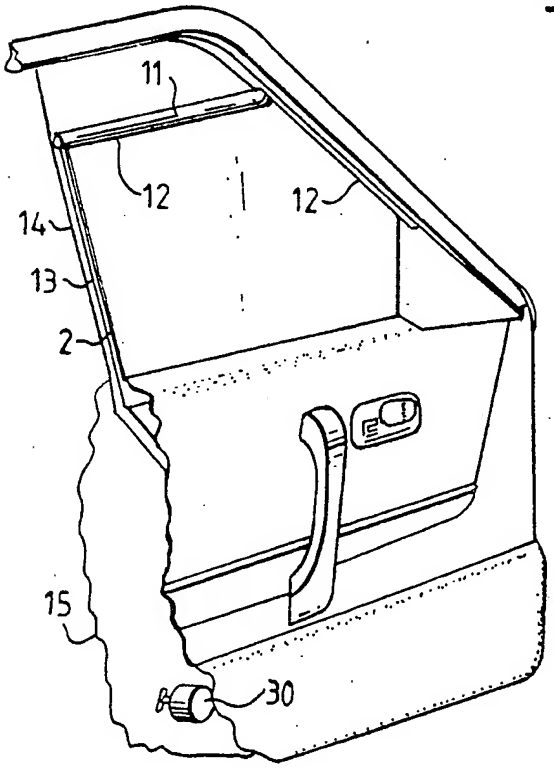

Fig.6.

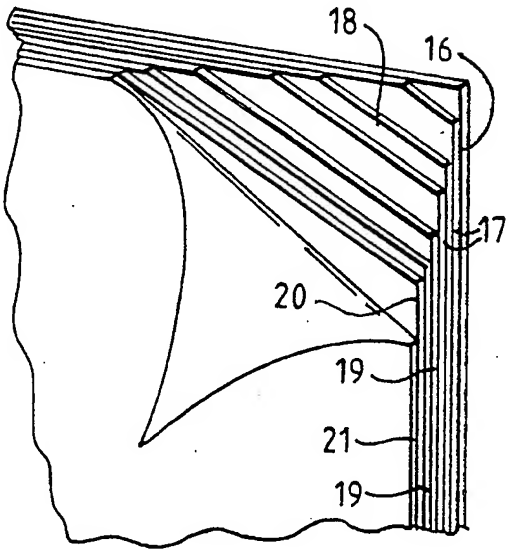

Fig.7.

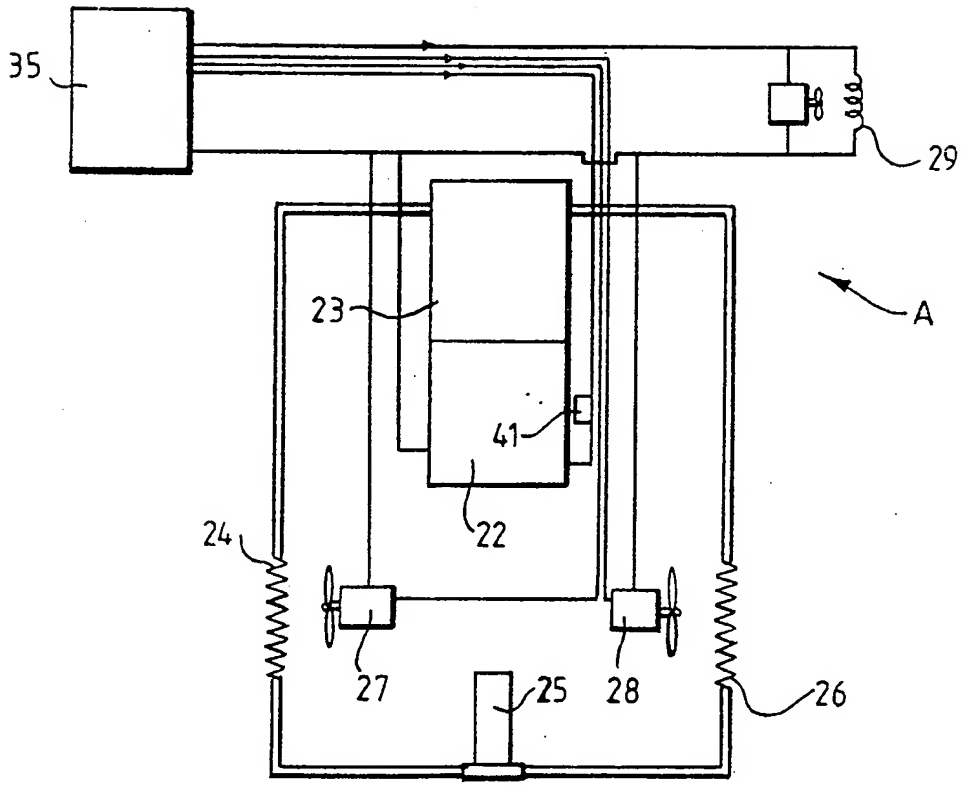

Fig.8.

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Fig.9.

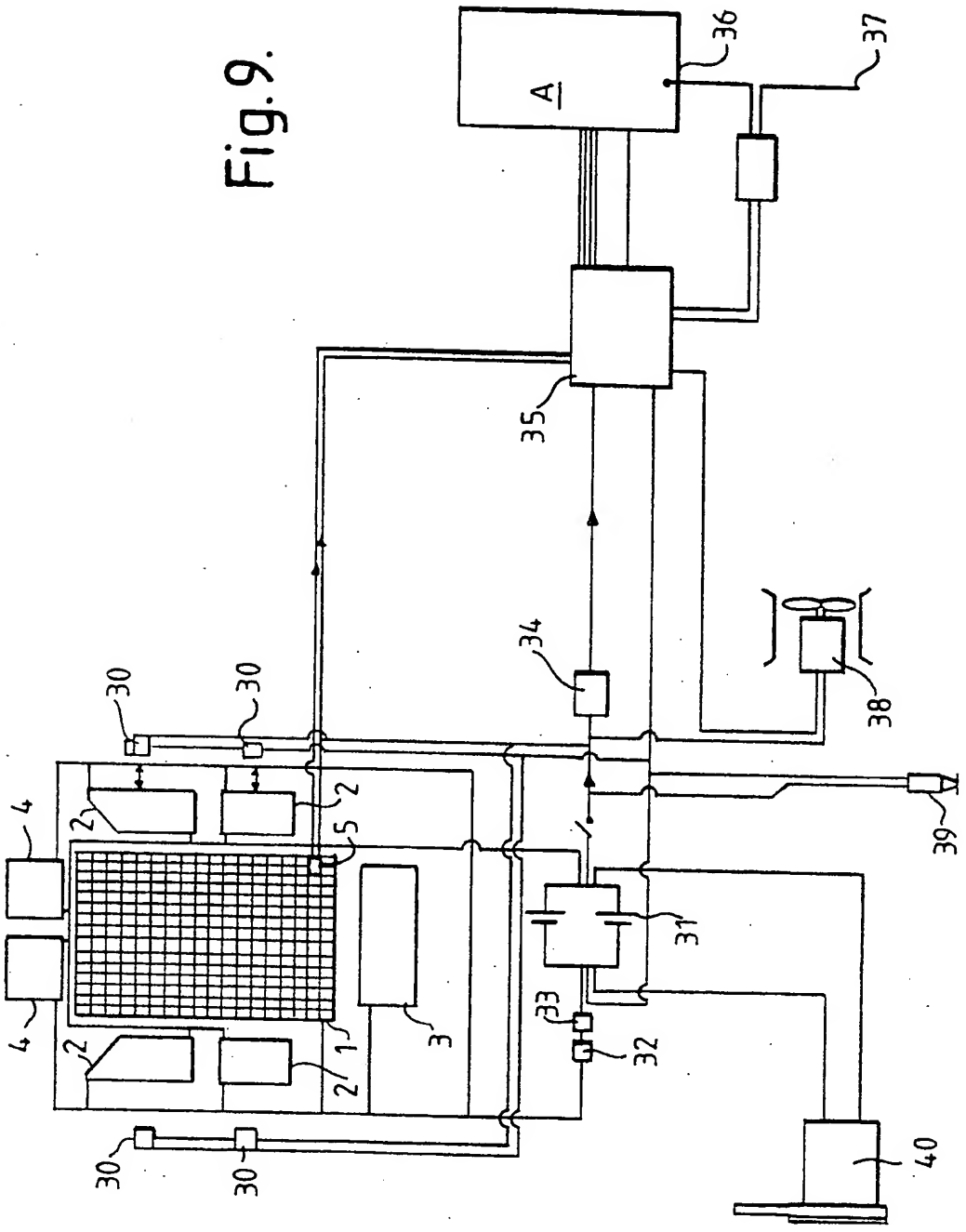


Fig.10.

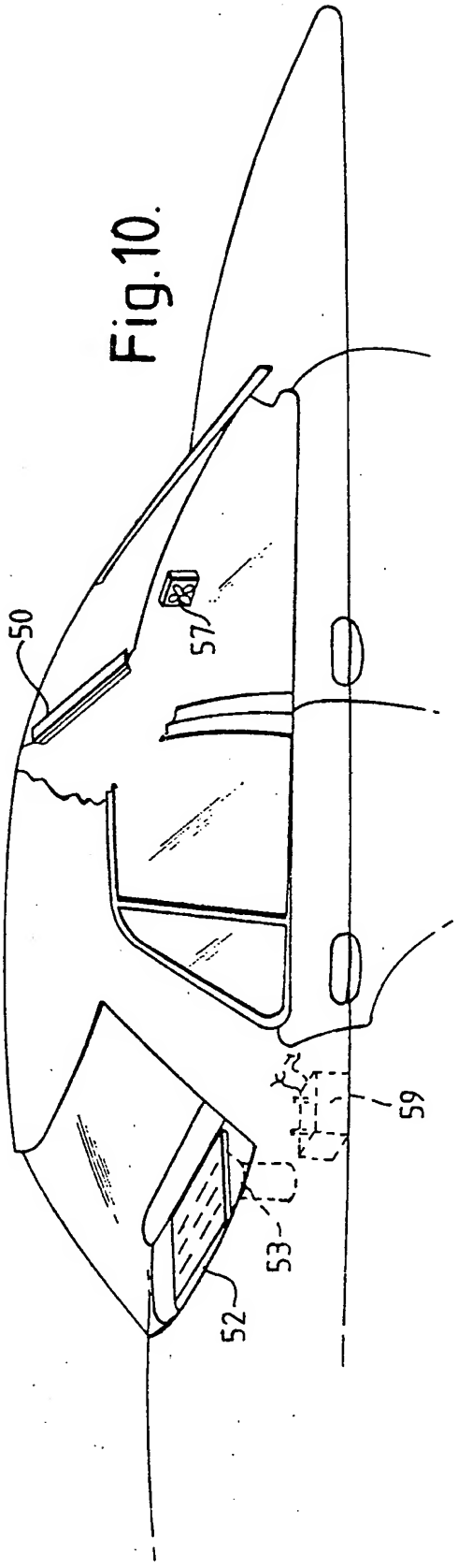
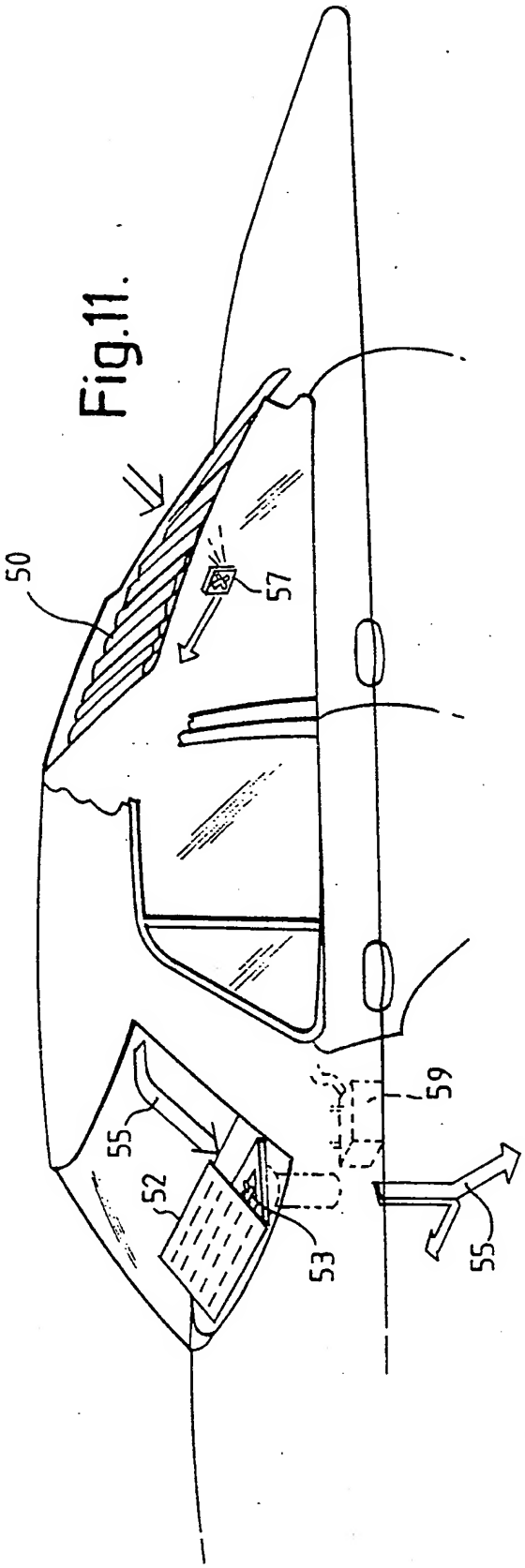


Fig.11.



SOLAR-POWERED COOLING/HEATING SYSTEM

The present invention relates to systems which are at least partially solar-powered for cooling and/or heating a passenger compartment of a vehicle.

Parking an enclosed vehicle in direct sunlight can cause the air temperature in the vehicle's passenger compartment to increase markedly in relation to the ambient air temperature. This temperature increase is largely due to the so-called greenhouse effect in which the sun's rays pass through the vehicle's windows and heat the vehicle's interior fittings. The fittings give off heat in turn but little of this heat is radiated back through the windows and therefore the air temperature in the passenger compartment rises.

In strong sunshine, the air temperature in the passenger compartment may rise to 50° or more, a temperature which can damage plastics components, electronic equipment and other heat-sensitive items. Moreover, the temperature difference between the interior and the exterior of the vehicle can cause problems when a person enters the vehicle in view of the temperature change to which the person must adapt. This temperature change may be perhaps 30°C or more, especially if the person has just left an air-conditioned environment of below-ambient temperature. Furthermore, if the vehicle is equipped with its own air-conditioning system, the air temperature in the passenger compartment may drop sharply once the system comes into operation and therefore the person must adapt to a further temperature change. These temperature changes may have a deleterious effect, and may be particularly harmful to an elderly or infirm person.

One common partial solution to this problem is to cover the windows of the vehicle with opaque, insulating

material to provide shade. This is not very effective. An exhaust fan continuously operating to draw air through the passenger compartment is another solution but this can impose too great a strain on a vehicle battery so that it may be impossible to start the engine again.

It is well known to generate electricity from sunlight by the use of modules containing arrays of photovoltaic cells. For example such foldable solar modules are used as a power source for satellites. See, for example, US-A-3 785 590 and US-A-4 555 585. It is clearly possible to intercept the solar energy falling in a passenger car or similar vehicle. For example US-A-3 973 553 proposes the use of a solar heat collector for use as a movable caravan awning. In this case the solar energy is collected by pumping water through pipes in the collector so that the water is directly heated. Photovoltaic cells have also been employed to generate power from solar energy for various purposes associated with a vehicle. For example see US-A-4 452 234 which shows a movable panel of solar modules consisting of photovoltaic cells mounted on a trailer. EP-A-0 204 562 proposes the use of a transparent solar module of photovoltaic cells in place of conventional glazing in a vehicle sun roof.

The present invention provides a system for heating and/or cooling the passenger compartment of a vehicle which makes use of photovoltaic modules not only to generate at least some of the power to drive an air conditioning system or similar but also to provide shade within the passenger compartment of a parked vehicle to restrict greenhouse effect heating. Accordingly the use of the system of the invention efficiently overcomes the technical problem of maintaining a passenger compartment of a vehicle at a reasonable temperature while the vehicle is parked without placing an excessive strain on the vehicle battery.

The invention is more particularly defined in the appended claims which also recite preferred features of the system.

Some embodiments of the invention will now be described, by way of example only, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a side view of a vehicle fitted with a first embodiment of a system according to this invention;

Figure 2 is a plan view corresponding to Figure 1;

Figure 3 is a sectional view through the vehicle of Figure 1;

Figures 4, 5, 6 and 7 are perspective views of details of this invention;

Figure 8 is a block diagram of an air conditioning system capable of being used in the present invention;

Figure 9 is a block diagram of the overall circuit for the system of Figures 1 to 8;

Figure 10 is a perspective view of part of a vehicle to which a further embodiment of a system is fitted, the system being in its non-operational position; and

Figure 11 is a similar view to Figure 1 in which the system is shown in its operational position.

Referring to Figures 1, 2 and 3 of the drawings, in a preferred embodiment of this invention a vehicle is provided with several solar modules each comprising an array of photovoltaic cells. One module 1 is situated on the roof 6 of the vehicle as this position ensures that at least some cells will usually be exposed to the sun's rays so that electricity generation can be consistent. Other modules are provided in the form of panels for positioning immediately behind the vehicle's windows. These modules are substantially opaque so that they prevent light and heat transmission through them to the interior of the vehicle and therefore provide shade in the passenger compartment. It

will, of course, be appreciated that the modules will allow as much light as possible to reach the photovoltaic cells. In the embodiment shown, the side and rear windows are each provided with one module 2,3 and the front windscreen has two modules 4.

The modules 2, 3 and 4 are movable so that they are normally retracted when not required so as to leave an uninterrupted view through the windows for driving, sightseeing or the like. Conversely, when the vehicle is left in sunlight, the modules are moved to an operative position behind the vehicle's windows. This increases the number of photovoltaic cells exposed to light, thereby increasing the potential for electricity generation, and also shades the interior of the vehicle from a large proportion of the sunlight falling on the vehicle.

The modules 2, 3 and 4 may be constructed in many different forms, but a preferred arrangement is illustrated in Figures 1 to 3. In this arrangement, the modules 3,4 for the front and rear windows are retractable between the vehicle's roof 6 and a lining 7 thereof and may be slid into position behind their respective windows manually or by motors. The modules 2 for the side windows are retractable into the vehicle's doors in the manner of the side window. The modules 2 are retractable independently of the side windows. Again, the modules 2 can be moved manually or by motorised means.

An alternative arrangement of the front windscreen module is illustrated in Figure 4. The or each module is concertina-folded so that in the retracted position it fits behind or instead of the existing sun visor provided at the top of the windscreen. The module may be extended by unfolding as shown to increase the number of photovoltaic cells exposed to light and to increase the area of the

windscreen shaded. It is envisaged that 50% or more of the windscreen area may be shaded by modules of this type.

Figure 4 shows an alternative embodiment of the rear window modules, in which the module may be raised from a retracted position parallel to the vehicle's rear shelf to an operative position substantially parallel to the rear window. It is preferred that the module is raised by a motor, and the module's inclination may be adjustable.

A preferred embodiment of the side window modules 2 is illustrated in detail in Figure 6. In this embodiment, provision is made to seal off the space 13 between the module 2 and the side window 14, so as to provide insulation by preventing the warm air from within the space 13 circulating around the passenger compartment. The sealing is preferably accomplished by means of a heat-resistant elastic roller 11 at the top edge of the module 2, which is arranged to come into sealing contact with the window 14. The diameter of the roller 11 is slightly larger than the thickness of the module 2. Weather strips 12 on the side edges of the module may also be provided to enhance sealing of the space 13.

The module 2 is movable by means of an electric motor 30 to cover a major portion of the area of window 14. In the illustrated embodiments, the modules 2 cover about two-thirds of the area of the side windows 14, although the area covered may be increased if permitted by law.

Figure 7 is a partially cut away view of one of the modules 2, 3, 4 and shows the construction from overlying sheets of low-iron tempered glass 15, E.V.A. 17, tedlar 20, and decorative vinyl 21 in the manner of present commercially-available photovoltaic cell arrays. The modules also include layers 19 of insulation material such as thermo-brite or compressed rockwool. Electricity is

preferably generated by a layer 18 of photovoltaic cells constructed of single-crystal, multi-crystal and/or amorphous silicon, although other appropriate materials may be used. Any known structure of photovoltaic cells may be used in the modules. Since such structures are known in the art no more detailed description will be given.

An electrical circuit diagram of the system is shown in Figures 8 and 9.

An air conditioning unit A (Figure 8) comprises a turbo compressor 23, a condenser 26, an evaporator 24, a gas drier 25, fans 27, 28 and an optional heating coil 29. A control unit 35 controls a high-torque motor 22 which drives the compressor 23 at variable speed. The control unit has a control input from a light intensity sensor 5 positioned to detect light intensity falling on the vehicle. Preferably the sensor 5 is positioned on the roof of the vehicle adjacent or integral with module 1. The motor 22 is driven at a speed which is just sufficient to keep the passenger compartment cool given the sun's intensity. If the light intensity falls below a threshold value at which insufficient energy will be generated by the solar modules to keep the compressor running, the control unit 35 switches the cooling unit off and starts a high-speed fan 38. The fan 38 extracts warm air from within the passenger compartment so that the cooler ambient air is drawn into the cabin. The ambient air may be drawn from the cooler, shaded area beneath the vehicle. The cooling unit can of course be restarted once the light intensity reaches an appropriate threshold value.

Two parallel batteries 31 are connected via a surge protector 32 and a voltage regulator 33 to the outputs of photovoltaic cell arrays of modules 1, 2, 3, 4. The batteries store energy produced by the photovoltaic cells and provide a power supply for the control unit 35 and air

conditioning apparatus A. A cigarette lighter plug (not shown) is provided for connecting the system to the vehicle's main electrical system as a back-up in case of emergencies.

The described system is preferably linked into the vehicle's ignition switch so as to be activated when the vehicle is parked in direct sunlight and the ignition key is turned to the 'lock' position. Once activated, the modules 2, 3, 4 move into their operative positions automatically although of course they must be manually operated if no provision is made for powered operation. If there is sufficient sunshine, a starter 41 then starts the motor 22 and it is envisaged that the cooling unit will keep the cabin air temperature a constant 4°C below the ambient air temperature while the compressor 23 is running. This temperature differential is maintained by means of two temperature sensors 36,37, one located outside the vehicle and one inside, which feed their signals to the control unit 35 so that the speed and cooling effect of the compressor can be regulated.

The energy level in the batteries 31 is continuously monitored by a sensor 34 which cuts off the complete cooling/heating system if energy levels fall below a threshold value. The threshold value is selected such that sufficient energy remains to power the fan 38 and to retract the modules 2, 3, 4 when required. Sensor 34 is arranged to reactivate the cooling/heating system once the battery charge returns to an acceptable level.

A heating coil 39 may be added to the cooling system if the vehicle is to be used in cold climates. The heating coil 39 is activated by the vehicle's operator when required, and it is envisaged that the heating coil could keep the air in the passenger compartment 4°C warmer than the ambient air. The temperature differential may be maintained

by sensors 36,37 and control unit 35 as before. The heating effect of the coil is enhanced by the layers of insulating material incorporated into the modules 2, 3, 4.

A small auxiliary alternator 40 is driven by the vehicle's engine. This alternator charges the storage batteries 31 while the vehicle is in motion. The alternator 40 consumes negligible engine power but ensures that the batteries 31 are sufficiently charged to start the cooling system running even when the vehicle is parked in the shade.

A second embodiment of the system which provides for cooling of the passenger compartment of a vehicle is shown in Figures 10 and 11. This system comprises two solar modules 50, 52. A concertina-folded module 50 similar to that shown in Figure 4 is stored at the top edge of the front windscreen as shown in Figure 10 so that it provides minimal obstruction of the driver's view when retracted. When unfolded into the operational position shown in Figure 11, the module covers up to 85% of the front windscreen area. The rear module 52 lies on the rear parcel shelf when in the retracted position as shown in Figure 10. A motor with associated drive arm (not shown) is provided to incline this module into its operational position in which it lies behind the rear windscreen. Depending on the depth of the rear parcel shelf, the module 52 can cover up to 50% of the rear windscreen. It will be appreciated that while uncovered the rear module can generate electricity to charge storage batteries even when the vehicle is in motion and the module is lying flat in its retracted position on the parcel shelf.

A pair of exhaust fans 53 have their inlets positioned in the parcel shelf so as to be exposed when the rear module is placed in its operational position. These exhaust fans are provided with ducting to direct air out from the passenger compartment of the vehicle to outlets beneath the

vehicle as shown diagrammatically by the arrows 55. An inlet fan 57 is mounted in the front of the passenger compartment with an inlet below the windscreen and an outlet into the passenger compartment producing air flow as shown by the arrows in Figure 11.

The electrical control system 59 for this system is similar in principle but simpler than that described with reference to Figures 8 and 9. The housing 59 is provided with electrical connections to the photovoltaic cells in both modules 50 and 52. The energy generated by these cells is used to charge a storage battery provided in the housing 59 which acts as a power supply for the fans 53 and 57. Light intensity sensors and differential temperature sensors as previously described are used to provide inputs to a control unit similar to unit 35 previously described which is mounted in the housing 59.

Ideally the capacity of the fans should be such as to be able to replace the total volume of heated air in the passenger compartment with air at the external ambient temperature within one minute. If necessary an additional inlet fan may be provided.

In this simpler system without a specific cooling arrangement for the air, it is possible to maintain the temperature of the passenger compartment at only 8-10°C above ambient. With existing solar cells it is necessary to provide greater power from increased solar cell area if an air conditioning system as described with reference to the first embodiment is to be powered.

The storage batteries charged from the solar modules may also be connected to the vehicle system to provide auxiliary power for starting the vehicle if there is low charge in the vehicle's own battery.

The systems described for use in vehicles may be adapted for application to buildings.

CLAIMS

1. A system for cooling and/or heating a passenger compartment of a vehicle, the system comprising

at least one movable, substantially opaque, photovoltaic module mounted in a passenger compartment of the vehicle behind a window thereof, such that it is movable between a retracted position in which the window is substantially unobstructed and an operational position in which the module is adjacent the window,

a battery for storing energy generated by the or each module, and

cooling and/or heating means at least partially powered by the energy generated by the or each module.

2. A system as claimed in claim 1, wherein at least one module is concertina folded in its retracted position and is unfolded in its operational position.

3. A system as claimed in claim 1 or 2, wherein at least one module is mounted so that it can be driven from a retracted position to an inclined position adjacent a window.

4. A system as claimed in any one of the preceding claims, wherein at least one module is retractable between the vehicle's roof and a lining thereof and is slidably movable into an operational position adjacent a window.

5. A system as claimed in any one of the preceding claims, further comprising a motor for driving an associated module between its retracted and operational positions.

6. A system as claimed in any one of the preceding claims, wherein a module is associated with a side window of the passenger compartment.

7. A system as claimed in any one of the preceding claims, wherein at least one module is provided with means for sealing between the module and the adjacent window along at least one edge thereof in the operational position.

8. A system as claimed in any one of the preceding claims, wherein at least one module comprises an array of photovoltaic cells backed by a layer of insulating material.

9. A system as claimed in any one of the preceding claims, further comprising a sensor for terminating operation of the cooling and/or heating means when the battery power falls below a preset level.

10. A system as claimed in any one of the preceding claims, wherein the cooling means comprises a drive motor, a turbo compressor driven by the motor, and means for drawing air over the compressor.

11. A system as claimed in any one of the preceding claims, further comprising an alternator driven by a vehicle engine for charging the battery.

12. A system as claimed in any one of the preceding claims, further comprising respective temperature sensors inside and outside the vehicle, the operation of the cooling and/or heating means being controlled to maintain a predetermined differential temperature.

13. A system as claimed in any one of the preceding claims wherein the cooling and/or heating means comprises at least one fan.

14. A system as claimed in any one of the preceding claims, further comprising a light sensor, the output of which is connected to control the operation of the cooling and/or heating means.

15. A system for cooling and/or heating a passenger compartment of a vehicle substantially as herein described with reference to Figures 1-9 or Figures 10 and 11 of the accompanying drawings.

16. A system for cooling and/or heating a space within a building, the system comprising

at least one movable, substantially opaque, photovoltaic module mounted in the space within a building behind a window thereof, such that it is movable between a retracted position in which the window is substantially unobstructed and an operational position in which the module is adjacent the window,

a battery for storing energy generated by the or each module, and

cooling and/or heating means at least partially powered by the energy generated by the or each module.

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